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METHODS OF WINTER-WHEAT PRODUCTION AT THE FORT HAYS BRANCH STATION.

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WINTER WHEAT IN ELLIS AND ADJOINING COUNTIES IN KANSAS.

The Fort Hays branch experiment station is located in Ellis County. This county is in the western tier of the solid block of 28 counties which with 2 others were designated in the 1901 report of the Kansas State Board of Agriculture [1] as "million-bushel" counties in wheat production.

The statistics gathered by the State Board of Agriculture and published in its biennial reports make it possible to follow the history of each crop from the beginning of agriculture in the county and the region and to determine the rotation and cultural problems as they present themselves in the accomplished fact of actual practice.

Ellis County is recorded as containing 900 square miles, or 576,000 acres. Since the first attempt was made at cultivation in 1870 the area under the plow has increased until in 1920 the total area for all crops reached 270,867 acres. But with the extension of the cultivated acreage the rate of increase is diminishing. A distinct break in the curve showing the total acres of all crops in the county is noted in 1903. For the 15 years preceding that date the increase

[1] Kansas. State Board of Agriculture. Biennial Report, v. [3–27], 1874–1919–20. Topeka, 1874–1921.

had averaged about 10,000 acres per year, but for the 15 years following it averaged only about 4,000 acres per year.

For the purpose of the present bulletin the most important thing is not the acreage under cultivation, but the proportion of it that is devoted to the different crops. All who have any knowledge of the agriculture of the section recognize the predominance of winter wheat, but probably few sense it as clearly as it is shown by the statistics. Table 1 shows for Ellis County for each year of the period from 1874 to 1920, inclusive, the total acres of all crops, the acres of winter wheat harvested, the acres of crops other than winter wheat, and the percentage of the area devoted to winter wheat as compared to all other crops. This table does not include prairie hay, the acreage of which is given and included in the totals published in the Biennial Reports of the Kansas State Board of Agriculture, [2] from which the data of this table are obtained.

TABLE 1.—*Acreage devoted to all crops (other than prairie hay) compared to that of winter wheat in Ellis County, Kans., each year for the 47-year period from 1874 to 1920, inclusive.*

Year.	Area cropped (acres).			Percentage of winter wheat to area devoted to all crops.	Year.	Area cropped (acres).			Percentage of winter wheat to area devoted to all crops.
	All crops.	Winter wheat.	All other crops.			All crops.	Winter wheat.	All other crops.	
1874	1,669	56	1,613	3.5	1898	161,463	123,631	37,832	76.6
1875	1,391	93	1,298	6.7	1899	183,144	148,562	34,582	81.1
1876	1,756	312	1,444	17.8	1900	176,268	137,597	38,671	78.1
1877	3,631	1,321	2,310	36.4	1901	197,346	166,108	31,238	84.2
1878	9,844	4,037	5,807	41.0	1902	210,078	178,367	31,711	84.9
1879	25,298	12,995	12,303	51.4	1903	214,929	184,602	30,327	85.9
1880	46,021	21,976	24,045	47.8	1904	207,726	172,553	35,173	83.1
1881	42,206	16,320	25,886	38.7	1905	221,313	181,081	40,232	81.8
1882	48,969	22,613	26,356	46.2	1906	223,389	171,028	52,361	76.6
1883	38,038	19,840	18,198	52.2	1907	237,095	185,264	51,831	78.1
1884	45,101	27,290	17,811	60.5	1908	238,665	187,358	51,307	78.5
1885	51,322	13,144	38,178	25.6	1909	243,083	191,189	51,894	78.7
1886	53,172	24,779	28,393	46.6	1910	247,780	159,305	88,475	64.3
1887	42,534	18,211	24,323	42.8	1911	152,340	78,170	74,170	51.3
1888	51,219	30,225	20,994	59.0	1912	248,507	157,908	90,599	63.5
1889	83,625	46,017	37,608	55.0	1913	244,099	163,537	80,562	67.0
1890	64,310	42,851	21,459	66.6	1914	261,642	234,890	26,752	89.8
1891	105,035	83,031	22,004	79.0	1915	229,187	190,188	38,999	83.0
1892	123,079	92,435	30,644	75.1	1916	269,840	210,203	59,637	77.9
1893	137,164	90,327	46,837	65.9	1917	245,270	16,478	228,792	6.7
1894	147,716	112,925	34,791	76.4	1918	275,244	158,579	116,665	57.6
1895	149,919	105,259	44,660	70.2	1919	277,456	226,207	51,249	81.5
1896	139,587	97,009	42,578	69.5	1920	270,867	199,682	71,185	73.7
1897	154,629	113,801	40,828	73.6					

Beginning with 1911, figures of the acreage seeded to winter wheat as well as of the acres allowed to remain after winter abandonment have been published. The latter are the figures tabulated in the biennial reports[2] used in Table 1. The decreases in the acres of winter wheat in some of the recent years have been due to seasonal conditions rather than to purposeful reduction by the farmers, as in no

[2] Kansas. State Board of Agriculture. Op. cit.

year since 1911, when the separate figures on acreage seeded begin, has less than 80 per cent of the total acres of all crops been seeded to winter wheat.

The percentage of the acres of winter wheat as compared to the acres of all crops in Ellis County is shown in Figure 1. The Ellis County ratios are indicated by dots connected with a solid line.

To determine whether the condition shown by the statistics to obtain in Ellis County were a true condition, common to the region and exhibited in other counties, similar data were abstracted and calculated for four adjoining counties: Rooks on the north, Russell on the east, Rush on the south, and Trego on the west. This study showed a remarkably close agreement between the percentage of total crop acres devoted to winter wheat in Ellis and Rush Counties. For

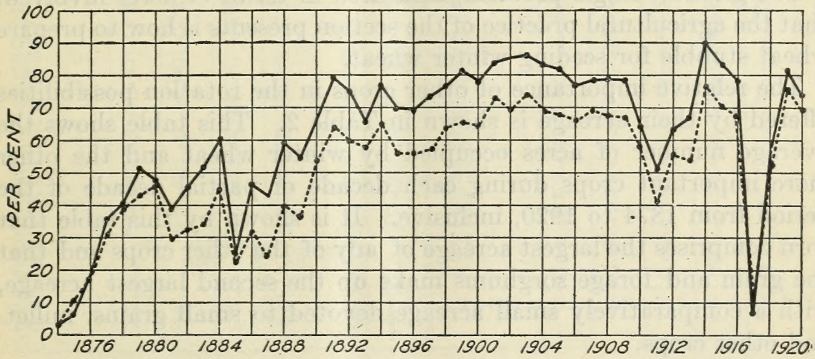

FIG. 1.—Percentage of the area (acres) of all crops occupied by winter wheat (harvested) in Ellis, County, Kans., shown by dots connected by a solid line, and the average of Ellis, Russell, Rush, Rooks, and Trego Counties, Kans., shown by dots connected by a broken line, for the 47 years from 1874 to 1920, inclusive. (From statistics published in the Biennial Reports of the Kansas State Board of Agriculture.)

the 30-year period from 1891 to 1920, inclusive, the ratio of winter wheat to all crops has averaged 0.731 in Ellis County and 0.723 in Rush. Russell has consistently devoted a somewhat lower ratio of its acreage to winter wheat, its average for the same years being 0.634. Rooks and Trego devote a still smaller acreage to wheat, the ratios for these counties for the same years being 0.504 and 0.511, respectively.

The average of the five counties is shown in Figure 1 by dots connected by a broken line. This diagram shows a rapid increase in the proportion of wheat to total crop acreage until 1891. This increase, however, was interrupted by a period of recession from 1879 to 1885 and is consequently divided into two periods of rapid increase, one from the beginning in 1874 until 1879 and one from 1885 until 1891. Since 1891, or for 30 years, the curve shows a condition of practical stability in the ratio of winter wheat to all crops. The

apparent drops in some of the recent years have been due to winter losses rather than to a restriction of the acreage attempted. It has been shown that winter wheat in Ellis and Rush Counties occupies about 72 of every 100 acres in crop. For Russell County the proportion is 63 and for Rooks and Trego about 50.

These statistics show that in such counties as Ellis and Rush if every acre in other crops were seeded to winter wheat only about one-third the total wheat acreage would be provided for. After this is done 2 of every 3 acres of wheat must still be sown directly following wheat. As every acre in other crops is not seeded to wheat it seems safe to conclude that in the area represented by the Fort Hays (Ellis County) branch station approximately two-thirds of the wheat is grown following winter wheat.

The greatest single problem, measured in terms of acres involved, that the agricultural practice of the section presents is how to prepare wheat stubble for seeding winter wheat.

The relative importance of other crops in the rotation possibilities offered by their acreage is shown in Table 2. This table shows the average number of acres occupied by winter wheat and the other more important crops during each decade or partial decade of the period from 1874 to 1920, inclusive. It is shown by this table that corn comprises the largest acreage of any of the other crops and that the grain and forage sorghums make up the second largest acreage, with a comparatively small acreage devoted to small grains, millet and other crops.

TABLE 2.—*Average numoer of acres in Ellis County occupied by winter wheat and the other more important crops during each decade or partial decade of the 47-year period from 1874 to 1920, inclusive.*

Decade.	Areas cropped (acres).											
	Winter wheat.	Rye.	Spring wheat.	Corn.	Barley.	Oats.	Potatoes.	Sorghum.	Millet.	Milo.	Kafir.	Alfalfa.
1874 to 1880...	5,827	206	239	3,825	60	494	139	69	1,536	.....	.....	.....
1881 to 1890...	26,129	4,013	740	7,934	373	2,794	435	3,053	3,972	.....	.....	.....
1891 to 1900...	110,458	2,438	156	13,366	4,467	3,491	557	6,110	3,672	28	2,194	201
1901 to 1910...	177,686	524	175	21,553	3,272	2,349	630	5,883	3,340	47	6,806	1,677
1911 to 1920...	163,584	403	8	33,065	7,873	6,072	651	12,155	1,592	1,799	15,448	2,248

The effect that this heavy cropping to wheat may be having upon yields is an important question worthy of the most careful study. A period of 47 years would seem to be sufficiently long to afford conclusive evidence on the single concrete question of whether yields are increasing, unchanging, or decreasing; but on examination it is found to be relatively short when considered in connection with the great fluctuations in yields from year to year and for irregularly recurring periods of years.

The average yields of winter wheat per acre each year in each of the five counties, Ellis, Russell, Rush, Rooks, and Trego, are presented in Table 3. In the last column of the table the average yield of the five counties for each year is given.

TABLE 3.—*Average yields of winter wheat in Ellis, Russell, Rush, Rooks, and Trego Counties, Kans., for each year for the 47-year period from 1874 to 1920, inclusive.*

Year.	Yields per acre (bushels).						Year.	Yields per acre (bushels).					
	Ellis.	Russell.	Rush.	Rooks.	Trego.	Average.		Ellis.	Russell.	Rush.	Rooks.	Trego.	Average.
1874	20	.....	.....	.....	.....	20.0	1899	8	9	6	9	6	7.6
1875	16	18	15	.....	.....	16.3	1900	17	21	16	16	14	16.8
1876	12	12	11	.....	.....	11.7	1901	11	16	9	13	11	12.0
1877	20	20	19	19	.....	19.5	1902	4	3	4	9	8	5.6
1878	22	23	23	22	.....	22.5	1903	17	18	18	20	18	18.2
1879	7	10	3	11	.....	7.8	1904	9	13	8	9	5	8.8
1880	3	6	6	6	3	4.8	1905	5	10	7	14	9	9.0
1881	11	12	.....	10	11	11.0	1906	5	14	6	10	6	8.2
1882	21	20	16	23	19	19.8	1907	9	11	7	12	5	8.8
1883	13	11	9	15	8	11.2	1908	14	14	12	13	6	11.8
1884	27	29	26	29	23	26.8	1909	6	11	8	13	10	9.6
1885	7	8	10	8	7	8.0	1910	13	16	15	12	6	12.2
1886	16	14	14	14	12	14.0	1911	2	4	6	4	3	3.8
1887	15	7	8	10	8	9.6	1912	12	15	10	16	8	12.2
1888	13	15	10	17	13	13.4	1913	6	6	3	7	2	4.8
1889	26	24	24	20	10	20.8	1914	19	19	22	21	19	20.0
1890	9	9	9	9	5	8.2	1915	11	13	10	14	10	11.6
1891	12	16	7	20	16	14.2	1916	13	13	13	15	22	15.2
1892	20	21	18	22	17	19.6	1917	2	5	4	3	3	3.4
1893	.27	.05	.16	.6	0	.2	1918	9	10	6	7	6	7.6
1894	2	1.65	.48	2.7	3	2.0	1919	9	11	9	11	9	9.8
1895	4	3	4	1.5	6	3.7	1920	18	17	16	25	20	19.2
1896	5	7	4	7	6	5.8							
1897	15	12	12	12	14	13.0	Average..	11.6	12.7	10.5	12.8	9.7	11.
1898	12	16	8	10	9	11.0							

If these yields are studied as a whole by determining each year the average of all yields available at that time, a generally falling average yield is shown. The decrease, however, is becoming very small in recent years. Such a study alone would lead to the conclusion that yields are decreasing. But a further study shows that this apparent continuing decrease is due entirely to the persistent effect on the average of the high yields obtained in the early years. The high yields in the early years are shown most effectively in Table 4. In this table the yields given in Table 3 are averaged by decades and partial decades. In this table, as in these statistics in general, the evidence of each county is confirmed by that of the others.

The average of the five counties shows for the 7-year period from 1874 to 1880 an average yield of 14.1 bushels, for the decade 1881 to 1890 an average of 14.4 bushels, for the decade 1891 to 1900 an average of 9.6 bushels, for the decade 1901 to 1910 an average of 10.4 bushels, and for the decade 1911 to 1920 an average of 10.8 bushels.

This shows a higher average in the seventies and eighties than has been attained since and indicates a maintenance of yields during the three later periods. This phase of the question will be studied more in detail than simply by the decade averages.

TABLE 4.—*Average yields of winter wheat in Ellis, Russell, Rush, Rooks, and Trego Counties, Kans., for each decade or partial decade of the 47-year period from 1874 to 1920, inclusive.*

Decade.	Average yields per acre (bushels).					
	Ellis.	Russell.	Rush.	Rooks.	Trego.	Average.
1874 to 1880	14.3	14.8	12.8	14.5	.....	14.1
1881 to 1890	15.8	14.9	14.0	15.5	11.6	14.4
1891 to 1900	9.5	10.7	7.6	10.1	10.1	9.6
1901 to 1910	9.3	12.6	9.4	12.5	8.4	10.4
1911 to 1920	10.1	11.3	9.9	12.3	10.2	10.8

In considering acreage it was noted that the year 1891 marked the time when stability was reached in the proportion of wheat to all crops. If the previous period be eliminated and the study of yields is begun with that year, the curve is very different from the one obtained when it is included. In the nineties yields were high, low, and again high. The 10-year average of Ellis County for 1891 to 1900, inclusive, was 9.5 bushels per acre. The succeeding averages obtained by including the data of each succeeding year in a new average until a 30-year average is obtained in 1920, do not depart from this by more than 0.5 bushel in either direction. The 24-year and 25-year averages were exactly the same as the 10-year average; the 29-year average was 0.1 bushel lower, and the 30-year average 0.1 bushel higher. The average of the five counties parallels that of Ellis very closely.

It is impossible to recognize any progressive change in yields during this period of 30 years.

In the early years a lesser area of land was under cultivation, as well as a smaller proportion of it in wheat. The smaller acreage perhaps contributed to more timely work. Undoubtedly the best land as a rule was brought under cultivation first. During the development period a considerable proportion of the wheat would be seeded on newly broken prairie sod or on land only a few years from sod. Such land is free from the weeds and diseases that follow a crop after its introduction into a new country.

With the passage from first development to a stabilized condition on old soil there was a marked drop in yields. The term old soil is intended to express only a relative condition as distinguished from new land which still enjoys the physical effect of the prairie sod and its relative freedom from the weeds and diseases that accompany cropping. The evidence of a number of dry-land experimental farms seems to show this change occurring in from four to seven years on individual fields and farms.

Since the drop that marked the passage to a stabilized condition there has been no measurable change in yields. If the system in itself has resulted in any decrease of yields, such decrease has been

overcome by other factors tending to improvement, such as better varieties, treatment of seed, and the attainment of a higher average degree of efficiency of methods and machinery. There has been an almost perfect balance between the factors of decrease and increase. With an agriculture established for 30 years by devoting nearly 75 per cent of the cultivated acreage to winter wheat an unchanged average of yields has been maintained.

COOPERATIVE EXPERIMENTS IN METHODS OF WHEAT PRODUCTION AT THE FORT HAYS BRANCH STATION.[3]

The Fort Hays branch station of the Kansas Agricultural Experiment Station is one of the points at which the Office of Dry-Land Agriculture Investigations of the United States Department of Agriculture first arranged for cooperative work in the investigation of methods of crop production. Field experiments in crop rotation and cultural methods were started under this cooperation in 1906. The work at that time was started on 100 plats. None of these have been dropped nor their continuous history interrupted, but their number has been increased from time to time until 326 plats were occupied in 1920. Of this number 136 were in winter wheat.

Other crops, presented in the order of the number of plats occupied by each, are kafir, corn, oats, barley, spring wheat, milo, alfalfa, brome-grass, sorghum, field peas, and winter rye. The two last mentioned are plowed under for green manure.

In the first part of this bulletin figures were presented showing the acreage devoted to each crop by the farmers of the region. The averages of the annual yields obtained on the experiment-station plats tend in the main to justify, with one exception, the relative importance assigned to the several crops by the farmers. According to the station figures, corn occupies a higher place in the acreage of the region than it is entitled to by its yield.

The average yields in bushels per acre for the 15 years since the experiments were started in 1906 are as follows: Winter wheat, 16.1; spring wheat, 5.1; oats, 18.5; barley, 15.8; corn, 5.4; kafir, 14.9; and milo, 15.7.

The problem of wheat production in this section has been presented concretely and with it the obvious question of what is the experiment-station evidence on the possibility of increasing the average yield and increasing it profitably.

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[3] The Office of Dry-Land Agriculture Investigations was organized in 1906 with E. C. Chilcott as Agriculturist in Charge, who planned, outlined, and instituted these investigations and who still has general supervision of them. This bulletin has been prepared under his direction.

L. E. Hazen had immediate charge of the cooperative work in 1906, 1907, and 1908. Since 1909 it has been under the immediate charge of the junior writer.

The work is closely coordinated with that at 23 other stations on the Great Plains, and the conclusions are therefore presented with a greater degree of confidence than they would be were they based entirely upon the results of the single station.

The most valuable evidence perhaps is that from the oldest block of plats, which have a continuous record from 1906 to 1920, inclusive. There are 14 plats of winter wheat in this block. Four of these are cropped continuously to winter wheat by different methods, one is on fallow in a 2-year rotation (or alternation of wheat and fallow), seven are in 4-year rotations, and two are in 6-year rotations containing brome-grass or alfalfa.

The land had been under cultivation for some years before the experimental work was started. The experiments being started in the spring of 1906, spring wheat was sown that year. Results with winter wheat are available for the 14 years from 1907 to 1920, inclusive. The yields from the 14 plats and also the average yield of the county for each year of this period are given in Table 5. The 14-year averages are shown at the bottom of the table.

TABLE 5.—*Yields of winter wheat in Ellis County, Kans., and in 14 plats at the Fort Hays branch station for the 14-year period from 1907 to 1920, inclusive.*

Year.	Ellis County.	Yields per acre for the several plats and rotations (bushels).													
		Continuous wheat.				C–D, fallow, wheat.	57, corn, barley, fallow, wheat.	51, corn, barley, rye,[a] wheat.	92, corn, barley, peas,[a] wheat.	55, kafir, barley, rye,[a] wheat.	56, kafir, barley, peas, wheat.	53, rye,[a] barley, corn, wheat.	54, peas,[a] barley, corn, wheat.	141, brome-grass (3 yrs.), oats, corn, wheat.	142, alfalfa (3 yrs.), oats, corn, wheat.
		A, late-fall plowing.	B, early-fall plowing.	E, subsoil.	F, list.										
1907	9	11.7	18.2	13.6	12.4	11.2	12.3	9.3	14.0	12.3	14.5	7.0	9.9	7.8	8.8
1908	14	25.6	23.3	30.5	28.1	32.3	29.2	21.8	(*b*)	23.2	9.4	11.7	11.9	11.3	9.4
1909 [c]	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1910	13	20.5	27.8	39.8	36.8	42.5	42.7	22.5	40.1	30.9	39.3	35.0	29.5	23.3	25.1
1911	2	0	.3	.3	.6	2.6	5.2	1.2	1.6	2.3	2.3	.5	.6	0	0
1912	12	2.3	13.8	20.1	26.6	29.2	27.7	0	4.9	13.2	10.1	8.6	13.9	19.0	12.9
1913	6	.8	2.3	4.1	8.4	10.3	16.4	8.7	6.8	8.1	4.6	2.5	8.1	11.6	6.5
1914	19	20.6	24.8	25.3	23.1	21.6	19.9	19.8	18.5	23.5	22.5	21.4	24.0	19.9	6.7
1915	11	9.3	13.1	14.9	13.9	11.3	17.5	19.8	21.3	21.8	20.4	18.8	20.7	21.0	19.7
1916	13	8.7	22.7	27.6	23.1	33.8	31.8	28.8	29.8	33.8	33.2	31.5	36.6	34.8	23.5
1917	2	0	2.0	2.6	0	7.1	3.3	5.3	1.5	3.8	1.7	.3	.3	0	0
1918	9	9.7	14.9	14.4	24.8	35.8	12.6	4.7	13.7	12.0	13.7	10.7	9.3	9.4	9.3
1919	9	17.9	16.8	18.9	19.8	10.0	13.5	14.6	11.0	13.7	12.7	20.6	24.7	21.8	20.3
1920	18	19.9	24.4	26.0	24.2	37.0	33.3	30.9	31.1	32.6	32.2	27.8	37.7	30.0	29.1
Avge.	10.2	10.5	14.6	17.0	17.3	20.3	19.0	13.4	14.9	16.5	15.5	14.0	16.2	15.0	12.2

[a] Plowed under for green manure. [b] Spring wheat by error. [c] All wheat on the plats destroyed by hail.

CONTINUOUS AND ALTERNATE CROPPING TO WHEAT FOR 14 YEARS.[4]

Of these 14 plats the greatest interest attaches to the four that are continuously cropped to wheat and the two on which wheat and fallow alternate. These have no rotation number but are designated as A, B, E, and F, continuously cropped, and C and D, on which wheat and fallow alternate. Plats C and D are located between plats B and E in the field. Plat A is late plowed and harrowed twice immedi-

[4] Since this manuscript was prepared the 1921 results have become available. They effect only minor changes in the averages and do not change the conclusions derived from them. The season was relatively unfavorable to wheat raised continuously without plowing, to late-fall plowing, and to wheat following corn and kafir. In the methods-of-fallow experiment the yield of the late-plowed plat in the pair N–O was relatively low and that of the listed plat in the pair P–Q was relatively high.

ately after plowing. It receives no other cultivation or treatment. Plat B is plowed as early as practicable after harvest, disked or harrowed immediately after plowing, and given such subsequent cultivation until seeding as may be necessary to prevent the growth of weeds and vegetation. This usually requires three or four cultivations with harrow, disk, or shovel cultivator. Plat E is given the same treatment as B except that it is subsoiled at the time of plowing. Plat A is plowed about 5 inches deep, B from 6 to 7 inches, and E plowed to the same depth as B and subsoiled an additional 7 to 9 inches. Subsoiling, however, is not done every year. It was done preceding the crops of 1907, 1908, 1911, 1914, 1917, 1919, and 1920. Plat F is furrowed with a lister at the time of plowing B and E. Furrows are run at distances of 3½ feet, the same as if planting corn, and to a depth of about 6 inches. Thereafter until seeding, the plat is given the cultivation necessary to prevent weed growth and to level the surface by seeding time. This usually requires one cultivation and two harrowings or two cultivations and one harrowing.

The average date of winter-wheat harvest on these plats has been July 1 and the average date of seeding September 29. A period of 90 days thus elapses between harvest and seeding. The average date of plowing plat A has been September 12, or 73 days after harvest and 17 days before seeding. Plat B has been plowed on the average date of August 2, 32 days after harvest and 58 days before seeding. Plat A thus lies in stubble for 41 days, practically six weeks longer than B; or, stated in another way, B is in a state of bare cultivation before seeding for six weeks longer than A. This period of six weeks in August and early September is a summer period when vegetative growth is very strong provided there is any moisture to support it. For the 14 years under consideration the August precipitation has averaged 3.13 inches. During the same period July has averaged 2.67 inches and September 1.96 inches.

It may seem that an interval of 32 days between harvest and plowing is unduly long and that any advantage from early plowing might be further enhanced by shortening it. But this is the period fixed by experience as the shortest practicable when the crop is harvested with the binder and thrashed from the shock. The weather causes delays, particularly in clearing the crop from the ground either by stacking or thrashing. Plowing, listing, or disking consumes considerable time, so it is improbable that for any considerable acreage the interval could be shortened in practice. Farms are not likely to be so equipped as to permit the simultaneous conduct of plowing and harvest operations. When the crop is harvested with a header, as much of it is in this section, cultivation may be started somewhat sooner than is possible where the grain is bound.

As exhibited in Table 5, the lowest yield has been from plat A. This has yielded not only the lowest of any of the plats continuously cropped to wheat but the lowest of any plat in the field. The seed bed is quite commonly described as loose and lumpy; germination and stand may be poor; winter survival is sometimes poor; growth is not as vigorous as on other plats; and it is one of the first to suffer from drought. Only twice in 14 years has its yield exceeded that of plat B. Its 14-year average yield of 10.5 bushels per acre is practically the same as the Ellis County average of 10.2 bushels for the same period. In exactly half the years its average has exceeded that of the county and in the other half it has been lower. As might be expected, the county average is smoother than that from a single plat or field because it neither descends to the complete failure nor rises to the height of high yields that the latter may experience.

Plat B, which is plowed one month after harvest, six weeks earlier than A and two months before seeding, has exceeded A in yield every year except 1908 and 1919. While A has a 14-year average of only 10.5 bushels per acre, the average yield of B for the same period is 14.6 bushels. This is an increase of 4.1 bushels per acre on account of the earlier plowing and subsequent cultivation. This stores water in the soil which protects to some extent against drought and prepares a generally moist and solid seed bed in which germination, fall growth, and winter survival are better than on the late plowing.

The yield from this method exceeds the county average by 4.4 bushels per acre. As it is a very practicable method of preparing wheat stubble for wheat it appears from the comparative results of these two plats alone that the county average should be susceptible of increase.

Plat E is a duplicate of B in time of plowing and in cultivation after plowing. As has been explained it is in addition subsoiled from time to time. Its yield averages 17 bushels per acre, or 2.4 bushels more than B. In following the yield of B it confirms the advantage of early plowing. It also appears to show some advantage from subsoiling. This increase from subsoiling is more marked at Fort Hays than at other dry-land stations and more marked with winter wheat than with other crops. The subject has been treated exhaustively in another publication.[5] Subsoiling would necessarily delay plowing, and so on a large acreage any increase from it might be neutralized by the poorer returns shown to follow late plowing.

Plats E and F lie side by side. As already described, plat F is listed instead of being plowed. Its yield follows that of E very closely, sometimes one and sometimes the other having the heavier yield. Its 14-year average is 17.3 bushels per acre. This is 0.3 bushel more

[5] Chilcott, E. C., and Cole, John S. Subsoiling, deep tilling, and soil dynamiting in the Great Plains. *In* Jour. Agr. Research, v. 14, no. 11, p. 481–521, 4 fig. 1918. Literature cited, p. 521.

than E, 2.7 bushels more than B, and 7.1 bushels more than A. Contrary to the objection of delay and increased cost raised against E, this method is quicker and cheaper even than B. With a given force the land can be listed more rapidly than it can be plowed, and consequently the benefits of early cultivation may be more fully realized with this method than with plowing. Except in 1917, when both this and the late-plowed plat A were reduced to total failure, it has generally stood drought better and longer than B. Plats E and F have generally been about the same in this respect, better than the continuously cropped plowed plats but not as good as the plat on fallow.

The other method in this series of plats that grow wheat alone is alternate wheat and fallow on plats C and D. In the even years C is cropped and D fallowed and in the odd years D is cropped and C fallowed. By using twice the area of land a crop is thus produced each year on fallow for comparison with those obtained by continuous cropping. The 14-year average yield from this method is 20.3 bushels. This is practically double the county average, only a fraction of a bushel less than double the average from late plowing, less than 50 per cent increase over early plowing, and only 3 bushels per acre more than early listing. The yield of fallow from this method and of fallow and of green manure throughout this bulletin is the yield from the area actually in crop. In computing the economic value of these methods consideration must be given to the fact that an equal area in preparation for a crop is producing nothing.

It not infrequently happens that the greater water supply and other more favorable conditions of this method promote a growth so heavy that it suffers from lodging and fungous diseases. When conditions do not continue so favorable the heavier vegetative growth of this method may demand more water than is available from both that stored in the soil and supplied by rain and the damage to it from drought be relatively and actually greater than to plats having less growth because they started under less favorable conditions.

The evidence of the plats indicates that on land cropped to wheat alone the fallow can not be profitably employed on such acreage as it is possible to cultivate early, but that land that can not be prepared early might better be fallowed than seeded on a late-plowed poor seed bed. The principle of the fallow (cultivation to form a firm, moist seed bed and the storage of water before seeding) is correct, but the greater part of its benefits may be realized by cultivation in the period of three months between harvest and seeding. These are conclusions based on the averages of 14 years. They may not hold true in any one individual year. A heavy rainfall in the fallow period and a drought or deficiency of rainfall in the growing period favors the fallow. Drought during the fallow period decreases the

initial advantage of the fallow, and heavy rainfall in the growing period may put it at an actual disadvantage.

The relation of the moisture in the soil at seeding time to the yield of winter wheat has been discussed in detail in a previous publication,[6] which presents the data of both yield and soil moisture from these plats for the years 1907 to 1913, inclusive.

The evidence of these plats discloses nothing new. The value in this section of early preparation of wheat stubble when it is to be resown to wheat has been demonstrated often and is well known. But the length of the record and the relation of the yields to the average yield of the county makes an impressive object lesson. The low average for the county indicates that by far too large a proportion of the acreage is late and poorly prepared. The average is of course lowered by many other things besides failure to prepare the land early, but the importance of timely work and its necessity on a larger proportion of the acreage if the general average is to be increased can not be over emphasized.

Bulletin 178 of the Nebraska Agricultural Experiment Station[7] reporting results from the North Platte substation shows a much smaller increase from early-fall plowing than has been obtained at the Fort Hays branch station.

A simultaneously prepared manuscript on winter wheat in western Nebraska by L. L. Zook, published as Bulletin 179 of the Nebraska Agricultural Experiment Station, reports results with winter wheat following winter wheat, corn, fallow, and green manure at the North Platte (Nebr.), Scottsbluff (Nebr.), Akron (Colo.), and Ardmore (S. Dak.) stations. While all of these stations show relatively small increases from early preparation where the crop follows winter wheat or other small grain, they also show marked increases in yield where it follows corn, green manure, or fallow. The relations between yields from continuous cropping to winter wheat and from other methods at these stations are similar to those obtaining between late plowing of continuously cropped ground and other methods at the Fort Hays branch station.

These stations are farther north, at higher altitudes, and have less precipitation than Fort Hays. Harvest is later and frost and seeding are earlier. The growing period after harvest being shorter and drier than at Fort Hays, there is less opportunity for conducting an effective fallow between harvest and seeding. On the other hand, the lower precipitation at these stations contributes to a greater response from the full fallow period.

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[6] Call, L. E., and Hallsted, A. L. The relation of moisture to yield of winter wheat in western Kansas. Kans. Agr. Exp. Sta. Bul. 206, 34 p., 12 pl. (in text). 1915.

[7] Zook, L. L. Winter wheat seed-bed preparation. Nebr. Agr. Exp. Sta. Bul. 178, 16 p., 2 figs. 1921.

WHEAT IN ROTATIONS FOR 14 YEARS.

Of the nine plats of wheat grown in rotations in this block, two follow immediately after peas as green manure, two follow rye as green manure, four are on disked corn ground, and one on fallow.

The highest average yield has been from the one on fallow in rotation No. 57. This is a 4-year rotation of fallow, winter wheat, corn on spring-plowed wheat stubble, and barley on disked corn ground. The wheat has averaged 19 bushels per acre. This should be compared with the yield of 20.3 bushels on fallow in the alternately cropped plats C and D that have been considered. The two have followed each other very closely in yield except in 1918, when the alternately cropped plat was very high and rotation No. 57 very low. For the other 13 years there is an average difference of only 0.3 bushel in favor of rotation No. 57.

No one of the other eight plats in rotations has averaged as much as either plats E or F continuously cropped to wheat.

Rotation No. 51 is the same as No. 57, except that in place of the bare fallow a crop of winter rye is turned under as green manure. This is plowed under on the average date of May 31. Thereafter until seeding, the ground is given the necessary cultivation, like the fallow, to keep it free from vegetation. Its average yield is only 13.4 bushels per acre.

Rotation No. 55 is the same as No. 51 except that it contains kafir instead of corn. It is rye for green manure, wheat, kafir, and barley. Its average yield of wheat is 16.5 bushels. It appears that the greater part, if not all, of the difference in the yield of wheat in this rotation and in rotation No. 51 is due to plat variation and experimental error rather than to the fact that one has kafir and the other corn two years before the wheat. Nearly 1 bushel of the difference is accounted for by the failure of the wheat in rotation No. 51 in 1912. This was caused by fall and winter soil blowing and was unquestionably due to location in the field. The average of the two plats following rye for green manure, one in rotation No. 51 and one in rotation No. 55, is 15 bushels per acre. This is only 0.4 of a bushel more than wheat on early plowing, less than wheat on subsoiled or early-listed ground, and 4.7 bushels less than the average of the two plats on fallow.

Rotation No. 92 is similar to No. 51, and rotation No. 56 is similar to No. 55, the difference being the replacement of the rye by a legume for green manure. Rotation No. 92 is peas for green manure, winter wheat, corn, and barley, and rotation No. 56 is peas for green manure, winter wheat, kafir, and barley. In the first four years, from 1906 to 1909, inclusive, cowpeas were used, but beginning with 1910 a change was made to field peas. Cowpeas grow in late season and are

not ready to plow under until in September. The average date for plowing under field peas has been June 20. This is three weeks later than the plowing under of rye, but the fallow period is more comparable than it could be with cowpeas. Rye, being ready to plow under three weeks earlier than peas, has a fallow period that much longer, and there is that element of difference in addition to the difference in the character of the crop. It is a difference, however, that is inherent in the nature of the crops and can not well be avoided. The average yield of wheat in rotation No. 92 is 14.9 bushels and in rotation No. 56, 15.5 bushels. Again, in this pair the higher yield is from the rotation having kafir instead of corn two years before the wheat. The difference, however, is too small to be significant. Rotation No. 92 has no record for 1908, as winter wheat was omitted from it by error. It was seeded to spring wheat, but the yield can not be used in comparisons with winter wheat. The average yield of the two plats following peas used as green manure is 15.2 bushels per acre. This is 0.2 bushel more than the average of the two plats following rye used as green manure. Each of the plats on peas has yielded more than one of the plats on rye, but less than the other.

The evidence presented by the wheat crop alone is not sufficient to distinguish any difference between a legume and a cereal as green manure. Any minor difference there may be is of little significance in comparison with the fact that neither one has produced yields as high as the less expensive bare fallow and only barely or not quite equal to those obtained from the best methods of preparation following a wheat crop. With the longer fallow period enjoyed by the green-manure plats it seems that their yield should exceed that following a wheat crop and more nearly approach that of the still longer period of the bare fallow. This is their general behavior at most dry-land stations.

Two other 4-year rotations contain green manure. Rotations No. 53 and No. 54 are similar to No. 51 and No. 92, with the positions of the corn and green manures exchanged. In these two the barley is on green manure and the wheat on disked corn ground. Rotation No. 53 is rye for green manure, barley, corn, and winter wheat, and rotation No. 54 is peas for green manure, barley, corn, and winter wheat. The average yield of wheat in rotation No. 53 is 14 bushels and in No. 54, 16.2 bushels per acre. This apparently shows a clear advantage of the legume over the cereal as a green manure that was not shown in the rotations where wheat immediately followed the green manure. The wheat in one of these rotations yields less and in the other more than wheat following wheat on early-fall plowing, but less in each than wheat following wheat on subsoiling or early listing. They of course yield markedly heavier than wheat following wheat on late-fall plowing.

While this discussion is confined to winter wheat, the data would be incomplete if the yields of the other crops in the rotations were omitted entirely. For convenience of reference, the average yields of the several crops in these rotations are shown in Table 6.

TABLE 6.—*Average yields of corn, kafir, barley,[a] and winter wheat in 4-year rotations at the Fort Hays branch station for the 14-year period from 1907 to 1920, inclusive.*

Item.	Yields per acre for the several rotations (bushels).						
	51, corn, barley, rye,[b] wheat.	92, corn, barley, peas,[b] wheat.	55, kafir, barley, rye,[b] wheat.	56, kafir, barley, peas,[b] wheat.	57, corn, barley, fallow, wheat.	53, rye,[b] barley, corn, wheat.	54, peas,[b] barley, corn, wheat.
Corn:							
Grain.....bushels..	5.5	7.5	.....	.....	6.6	4.9	5.4
Stover.....pounds..	2,514	2,410	.....	.....	2,361	2,315	2,417
Kafir:							
Grain.....bushels..	.....	.....	18.3	20.3	.....	.....	.....
Stover.....pounds..	.....	.....	4,648	4,698	.....	.....	.....
Barley.....bushels..	16.1	19.4	17.5	19.2	19.6	21.6	20.4
Wheat.....do....	13.4	14.9	16.5	15.5	19.0	14.0	16.2

[a] Barley is for the 13-year period from 1908 to 1920, inclusive. [b] Plowed under for green manure.

Corn following winter wheat the second year after rye used as green manure in rotation No. 51 has a 14-year average yield of 5.5 bushels of grain and 2,514 pounds of stover per acre. Corn on similar preparation after peas used as green manure in rotation No. 92 has averaged 7.5 bushels of grain and 2,410 pounds of stover per acre. In the similar rotation containing fallow instead of green manure, No. 57, corn has averaged 6.6 bushels of grain and 2,361 pounds of stover. Barley following the corn in these same rotations has averaged for the 13 years from 1908 to 1920, inclusive, 16.1 bushels in rotation No. 51, 19.4 bushels in rotation No. 92, and 19.6 bushels in rotation No. 57. It has been shown that the yield of wheat immediately following the green manure or fallow was 13.4 bushels after rye in rotation No. 51, 14.9 bushels after peas in rotation No. 92, and 19 bushels after fallow in rotation No. 57. When all three crops are considered the rye for green manure in rotation No. 51 shows to distinct disadvantage in comparison with peas or fallow. Between the other two rotations no choice is to be made from the behavior of the corn and barley, but for winter wheat the fallow rotation shows a distinct advantage over the one containing peas.

Rotation No. 53, rye for green manure, barley, corn, and winter wheat, has made average yields of corn, 4.9 bushels; barley, 21.6 bushels; and wheat, 14 bushels per acre. Rotation No. 54 is the same, with peas instead of rye for green manure. The average yields from it are corn, 5.4 bushels; barley, 20.4 bushels; and wheat, 16.2 bushels. Comparing the two rotations the higher yields of wheat and corn have been from the pea rotation and the higher yield of

barley from the rye rotation. It is doubtful whether the differences are significant.

The corn in these five rotations has made only three good crops. Some of the losses have been from grasshoppers and chinch bugs. These concentrate on the plats from the grain fields by which they are surrounded and sometimes cause losses which large fields would not suffer. To that extent the average may not be equal to the average that corn may attain in the section. But some of the losses have been from drought and hot winds, which are no more serious on plats than on larger fields.

The two rotations containing kafir have made average yields of 18.3 bushels of kafir grain and 4,648 pounds of stover in rotation No. 55, containing rye for green manure; and 20.3 bushels of grain and 4,698 pounds of stover in rotation No. 56, containing peas for green manure. Barley following the kafir has averaged 17.5 bushels in rotation No. 55 and 19.2 bushels in rotation No. 56. These yields of barley following kafir compare favorably with those following corn and are very nearly equal to the yields of barley following immediately after green manure. Barley in alternation with fallow on plats not previously introduced into this discussion has averaged 23 bushels per acre for the same period of years. The wheat in the rye rotation has averaged 16.5 bushels and in the pea rotation 15.5 bushels. These rotations clearly show the superiority of kafir over corn in the production of both grain and stover. The other crops in the rotations show no disadvantage from the kafir in them. Unfortunately there is not in this block any winter wheat immediately following kafir. The extent of work that could be started originally was limited, and the general experience and belief that wheat did not follow the sorghum crops successfully was accepted as sufficient reason for not including this method.

Two other rotations in this block introduce sod crops. Rotation No. 141 is oats on brome-grass sod, corn on spring-plowed oat stubble, winter wheat on disked corn ground, and three years of brome-grass. For several years the grass seed was sown in the winter wheat in the spring, but a stand was never obtained in this way. After failure to obtain a stand by this method the wheat stubble was plowed in the fall and the brome-grass seeded in the spring. Better results attended this method, but it is not always possible to get a stand and bring it through the summer. The rotation has been a failure as far as the grass crop is concerned. The only hay harvested was in 1916, 1919, and 1920. About half the time there has been a fair sod to break for oats. Breaking has been done in summer at the time of fall plowing. Oats have averaged 20 bushels per acre in this rotation, which is about the same as the average following grain crops, but in the years when a heavy sod has been broken the yield has been low.

Corn has averaged 6.3 bushels per acre, and wheat 15 bushels. This is about the average for corn and the same for wheat as the average of wheat on disked corn ground in the green-manure rotations.

Rotation No. 142 is the same as rotation No. 141, with alfalfa in place of brome-grass. The alfalfa is sown without a nurse crop in the first of the three years of alfalfa. Previous to 1913 not much success attended efforts to obtain a stand of alfalfa. Since that time there has always been a sod to break up, and generally there has been some hay production. The yield of oats has averaged 17.9 bushels per acre, which is less than in rotation No. 141 or from most methods by which oats have been raised. Corn has averaged 5 bushels per acre, which is next to the lowest yield of corn in this group. The average yield of wheat is 12.2 bushels, which is the lowest of any method except that of late plowing of wheat stubble.

These plats show clearly that the introduction of sod crops into the rotation will not increase yields, but has, on the contrary, the opposite effect to a degree largely dependent upon the success of the sod crop itself.

Diligent study has been made of the data from this block of plats to determine whether the averages for the entire period of experimentation afforded a correct basis from which to draw conclusions of the relative merits of the different methods and systems of cropping or whether some were having a cumulative effect in increasing or decreasing yields. The yield curves have been smoothed in various ways and the yields have been averaged for different periods and groups of years. Such studies have failed to reveal any changing relations in the yields of the different methods and rotations.

The evidence from the rotations in this block does not indicate that the farmers are wrong in devoting the large proportion that they do of the cropped acreage to winter wheat. Neither does it indicate that wheat grown following other crops yields more per acre than wheat following wheat, provided the stubble is plowed or otherwise cultivated soon after harvest so as to get the benefit of a fallow during the summer season between harvest and seeding.

METHODS OF FALLOW.

In presenting and considering in the foregoing pages the results on fallow, the method of fallow was not described. The method employed on those plats was what may be designated as the most intensive. Cultivation begins with early plowing after harvest. The ground is packed or worked down immediately after plowing and given during the summer and fall the cultivation necessary to prevent the growth of vegetation. The cultivation is in fact the same as early plowing to be sown to wheat. In the spring cultivation is continued. The ground is replowed in June and cultivation continued through

the summer until seeding time. The replowing is necessary to destroy the scattered deep-rooted weeds that may escape the surface-cultivating implements and to correct a fineness and compactness of surface that results from continued surface cultivation. Under this system a bare cultivated surface is maintained for about 14 months preceding seeding.

In 1913 an experiment was started to determine to what extent this fallow period might be shortened and the expense of the fallow reduced without reducing yields, or, more correctly speaking, to determine the effect on yields of reducing the length of the bare-cultivated period and the amount of work expended on the fallow. Four pairs of plats were set aside to be alternately cropped and fallowed. On the pair H–I the method above described was employed. These plats, therefore, duplicate the pair C–D from which results have been given. On the pair J–K the cultivated period is reduced by delaying the first plowing, which is the first cultivation, until late fall. This goes through the winter rough, as left by the plow, unless cultivation is necessary in winter to prevent blowing. The summer cultivation and replowing are the same as in the pair H–I. The plat to be fallowed in the pair L–M goes through the summer, fall, and winter in stubble. Its first cultivation is plowing in spring before vegetation makes very heavy growth. This usually has been in the last half of April. In 1915 this was replowed July 24; in 1916, August 1; and in 1918, June 13. By error it was plowed in the fall of 1913. In the summer of 1914 it was replowed August 20. In the pair N–O the bare-cultivation period is still further shortened by delaying the first cultivation until in June, when it is plowed. The actual dates of plowing have ranged from June 7 to June 24.

The yields from plats fallowed by these methods and others to be outlined are given in Table 7. The 7-year averages for the period 1914 to 1920 are 21.1 bushels from H–I, 21.6 bushels from J–K, 21.8 bushels from L–M, and 23.6 bushels from N–O. The first three methods run very close together, not only in the average but in each of the years. The last method was inferior in the drought of 1917 and decidedly superior in 1919. In 1919 those methods that had the rankest early growth and at one time the highest potential yield later suffered from lodging, storm damage, and fungous diseases and finally produced the lightest yield. This tendency, however, is not an unusual one at the Fort Hays branch station, and the performance record of methods that avoid it should not be discounted.

One year later, the experiment in methods of fallow was extended to include two more methods. The fallow plat in the pair P–Q is listed instead of plowed in the fall. The time of listing agrees in general with the time of plowing in the pair J–K. During the spring it is cultivated level, and it is plowed in June at the same time

the other fallow plats are plowed or replowed. Its treatment for the remainder of the season is the same as that of the others. The same method is followed in the pair R–S except that some time after listing in the fall a subsoiler is run in the lister furrows. Unfortunately it was necessary to locate this pair of plats in a block in another part of the field. The yielding power of the land is about the same, but results can not be compared too closely. The yields of these plats are also given in Table 7. For the 6-year period from 1915 to 1920, inclusive, the yield of P–Q has averaged 19.8 bushels and of R–S 22.2 bushels. In the same years H–I has averaged 20.1 bushels, J–K 21.0 bushels, L–M 21.3 bushels, and N–O 22.9 bushels.

The results of the whole experiment in methods of fallow show clearly that the essential period of the fallow is the summer months immediately preceding seeding. This conclusion was indicated in the continuous-cropping series by the close approach of the yields on early plowing to those on fallow. They also show, in connection with other experiments, that the essential part of the fallow is the maintenance of a bare surface (prevention of the growth of vegetation) during the active growing season and that the cultural methods by which this is accomplished are of minor importance from the standpoint of resultant yield.

TABLE 7.— *Yields of wheat from different methods of fallow at the Fort Hays branch station for the 7-year period from 1914 to 1920, inclusive.*

Year.	Yields per acre by the several methods (bushels).						
	Plats H–I. Early-fall plowed.	Plats J–K. Late-fall plowed.	Plats L–M. April plowed.	Plats N–O. June plowed.	Plats P–Q. Fall listed.	Plats R–S. Fall listed and subsoiled.	Rotation 570. Fallow 3 years.
1914	26.8	25.6	25.4	27.3	.....	.....	.....
1915	17.3	20.4	16.8	16.3	19.3	17.8	18.8
1916	33.6	37.3	38.2	41.2	37.2	38.0	33.1
1917	6.8	6.3	7.5	1.0	8.1	11.8	10.4
1918	15.3	14.1	14.5	18.3	11.8	17.2	28.8
1919	9.0	9.8	10.2	22.4	13.7	13.3	9.0
1920	38.8	37.8	40.3	38.4	28.9	35.0	33.8
Average, 1914 to 1920	21.1	21.6	21.8	23.6	.....	.....	.....
Average, 1915 to 1920	20.1	21.0	21.3	22.9	19.8	22.2	22.3

An experiment started in 1913 to provide material for the study of certain water relations of the soil is interesting in its evidence on the effect of the length of fallow. On the four plats known as rotation No. 570 the land is fallowed for three years and then cropped to winter wheat. These plats adjoin the pair R–S in the field. The yields from 1915 to 1920 are given in Table 7. The average yield for this period is 22.3 bushels per acre, which is less than the highest yielding plats with a single year of fallow. The only year when it

showed a marked superiority over the other methods was 1918. The result of this test tends to confirm the evidence that the full effect of the fallow in the region under consideration is realized by cultivation in the one summer prior to seeding.

WHEAT IN INTERTILLED STRIPS.

One of a group of experiments started in 1913 is a trial of wheat in intertilled strips. The single plat known as rotation No. 592 raises wheat continuously on early plowing. The wheat on this plat is sown with the ordinary drill set at the usual rate, but with a part of the feed cups closed so as to sow strips about 30 inches wide alternating with unseeded strips of the same width. The exact width has varied, depending upon whether a 6-inch, 7-inch, or 8-inch drill was used. As this and other experiments grouped with it were started in the spring of 1913, spring wheat was sown that year. In 1914 the methods under trial were in full operation and results are at hand for the 7-year period from 1914 to 1920, inclusive. The yields of this and other rotations or methods are given in Table 8.

TABLE 8.—*Yields of wheat by six different methods at the Fort Hays branch station for the 7-year period from 1914 to 1920, inclusive.*

Year.	Yields per acre by the several methods (bushels).					
	Rotation 592. Intertilled strips on fall plowing each year.	Rotation 591. Sown in stubble each year.	Rotation 401. Fallow, wheat, wheat, kafir.		Rotation 402. Fallow, wheat, kafir, kafir.	Plats N–O. In alternation with fallow.
			On fallow.	On fall-plowed wheat stubble.		
1914	18.3	21.3	22.2	20.7	15.6	27.3
1915	16.3	27.3	18.4	24.9	20.6	16.3
1916	25.1	23.7	38.1	41.3	27.6	41.2
1917	0	.3	7.9	1.1	8.8	1.0
1918	13.0	19.5	9.8	10.6	7.9	18.3
1919	18.3	23.7	15.3	24.6	16.3	22.4
1920	15.3	26.9	33.0	26.3	26.7	38.4
Average	15.2	20.4	20.7	21.4	17.6	23.6

GROWING WINTER WHEAT WITHOUT PLOWING.

The average yield of the intertilled wheat, designated rotation 592 has been 15.2 bushels. This yield may be fairly compared with 21.4 bushels on fall-plowed wheat stubble seeded solid in rotation No. 401, given in Table 8.

This method has sometimes been noted as standing drought better than solid seeding, but the limited number of plants have not been able to produce the yield of which the soil and water supply are capable.

The single plat known as rotation No. 591 grows wheat continuously without plowing. This plat was last plowed in 1912. It was double-disked, harrowed, and Acme harrowed in the fall of 1913,

and double-disked before seeding in 1916, 1918, and 1919. It has received no other cultivation or treatment except seeding and harvesting. Its average yield for the 7-year period from 1914 to 1920, inclusive, as shown in Table 8, is 20.4 bushels per acre. This may be properly compared with the yield of 21.4 bushels on early fall-plowed wheat stubble in rotation No. 401.

Further evidence on this subject is furnished by an experiment as to the frequency of plowing for winter wheat, which was started in 1916. This occupies six plats continuously cropped to winter wheat. Plat A is plowed each year, B is plowed one year and sown in stubble the next, C is plowed one year and sown in stubble two years, D is plowed one year and sown in stubble three years, E is to be sown in stubble continuously, and F, originally planned for another method, has been plowed each year except for the crop of 1917. The tillage on these plats is early plowing, which is worked down immediately and given necessary cultivation until seeding time. The plats sown without plowing receive no other treatment than a double-disking. In preparation for the crop of 1917 this was done at the time of early plowing. Since then it has been done at the time of late plowing. The yields from these plats for the 5-year period from 1916 to 1920, inclusive, are given in Table 9. The land was fallowed in 1915 and seeded that fall as a solid field. The plats were blocked out from the field in the spring of 1916. Differences in yield that year are natural differences between plats of uniform treatment. For 1917 plat A was plowed and the others seeded in disked stubble. All except plat A were consequently of uniform treatment. For 1918 plats A, B, and F were plowed, and C, D, and E were again seeded on disked stubble and again given uniform treatment. For 1919 plats A, C, and F were plowed, and for the fourth year D and E were seeded on disked stubble continued uniform. For 1920 plats A, B, D, and F were plowed, and uniformity between any of the plats disappeared.

In Table 9 the yields on plowed ground in the 4-year period from 1917 to 1920, inclusive, are printed in boldface type. Despite the plat variation, as shown by differences in yield when the treatment was uniform, the results are clear as to differences between plowing and not plowing in the years during which the experiment had been conducted, but they do not yet illuminate the question of how often plowing must be resorted to or how long it may be dispensed with. The average of each plat for the 4-year period from 1917 to 1920, inclusive, is given at the bottom of Table 9. In the present stage of the experiment perhaps a better comparison is afforded by determining the average yield each year of the plowed plats and of those not plowed. Such averages are shown in the right-hand columns of the table. In 1917 the one plowed plat was a total failure, due to a

thin stand and winterkilling, and five sown in disked stubble averaged 3.9 bushels per acre. In 1918 three plowed plats averaged 15.8 bushels and three not plowed 24.7 bushels. In 1919 three plowed plats averaged 19 bushels and three unplowed 22.2 bushels. In 1920 four plowed plats averaged 22.6 bushels and two unplowed 25.8 bushels. In four years the total gain from not plowing was 19.2 bushels, an average gain of 4.8 bushels per year. In this group of plats, as in rotation No. 591, which has not been plowed since 1912, there is no evidence of deterioration from the continued omission of plowing.

TABLE 9.— *Yields of wheat on plats continuously cropped to wheat but plowed at different intervals at the Fort Hays branch station for the 5-year period from 1916 to 1920, inclusive.*

[Yields following plowing shown by boldface type.]

Year.	Yields per acre (bushels).								
							Average.		Increase on unplowed plats.
	Plat A.	Plat B.	Plat C.	Plat D.	Plat E.	Plat F.	Plowed plats.	Unplowed plats.	
1916	33.8	39.8	35.2	37.4	35.9	38.8	.....	.....	.....
1917	0	2.6	3.8	4.9	2.8	5.6	0	3.9	3.9
1918	**10.8**	**16.0**	23.8	26.3	24.0	**20.5**	15.8	24.7	8.9
1919	**15.8**	20.5	**21.8**	22.3	23.8	**19.5**	19.0	22.2	3.2
1920	**17.5**	**21.1**	21.8	**23.4**	29.8	**28.5**	22.6	25.8	3.2
Average, 1917 to 1920	11.0	15.1	17.8	19.2	20.1	18.5	14.4	19.2	4.8

Near these plats in the field are two other rotations that were started in time to be productive of evidence on the same subject in 1919 and 1920. Rotation No. 568 is fallow, winter wheat on fallow, and winter wheat sown in stubble. Rotation No. 580 is the same thing lengthened one year by early plowing the last wheat stubble and raising a third crop of wheat before fallowing. In 1919 the stubbled crop was heavier than either that fallowed or plowed. In 1920 the fallowed was heavier than the stubbled, and the stubbled heavier than the plowed. As has been noted before, 1919 was distinctly unfavorable to methods that prompted a rank growth. In 1920 there was a similar tendency, but it did not go far enough to overcome entirely the initial advantage enjoyed by such methods as fallow.[8]

The somewhat anomalous condition is presented of early plowing or cultivation yielding heavier than late plowing, but no cultivation at all sometimes yielding heavier than either and averaging nearly as much as the best methods of early cultivation. The first is suscep-

[8] In 1921 the yield of the continuously stubbled plat known as rotation No. 591 fell to about one-half that of early plowing, but was still above that of late plowing. In the other experiments described, wheat sown in disked stubble on which plowing had been deferred for a lesser number of years maintained yields as high as on early plowing, or even higher.

tible of satisfactory explanation, but the reasons for the second condition are not so obvious. The stubble affords winter and spring protection to the wheat. It also catches snow during the winter and checks evaporation from the surface during the winter and spring. Then, as has been pointed out in considering the results on fallow, there are years when the heaviest early-season growth does not fulfil its prospects of making the heaviest crop of grain. The seven years covered by this phase of the experiments have embraced an unusual proportion of good wheat years and perhaps an unusual number of years favoring the poorer methods. It is therefore possible that a continuation of these experiments may not show as favorable results for the unplowed plats as has the period under discussion.

The data from the Fort Hays branch station and other field stations on the Great Plains show that in years sufficiently favorable to produce a crop, winter wheat is well able to compete with annual weeds because of the start it has over them in the spring. Spring-sown grains do not possess this ability to anything like the same degree, for the reason that the weeds start with such crops or even in advance of them. On this account plowing is of much greater import to spring-sown than it is to fall-sown grains.

The evidence indicates that on land free from perennial weeds and grasses annual plowing for winter wheat may not be as necessary an operation as has generally been believed.

CORN AND KAFIR AS PREPARATIONS FOR WHEAT.

In 1915 four 2-year rotations were started to compare corn and kafir as preparations for winter wheat and to determine the effect on the yield of wheat of limiting the stand of corn and kafir on the ground by planting only every other row.

Rotation No. 149 is corn ordinarily spaced, followed by wheat on disked corn ground. Rotation No. 150 is the same, but with the rows of corn twice as far apart. Rotation No. 349 is kafir ordinarily spaced, followed by wheat on disked kafir ground; and rotation No. 350 is the same with the kafir rows twice as far apart. Started in 1915 these rotations were in full swing in 1916. Table 10 gives the yield of wheat in these rotations for the 5-year period from 1916 to 1920, inclusive. These yields show a decided advantage of corn over kafir as a preparation for wheat. Limiting the stand of kafir has had a decided effect in increasing the yield of wheat, but with corn there has been little or no such effect.

The yield of wheat following even a one-half stand of kafir has not been equal to that following a full stand of corn. Wheat on fallow in rotation No. 560 adjoining these plats has averaged 20.2 bushels for the same years. This is a gain of 1.5 bushels over ordinary-spaced corn and only 0.3 of a bushel over double-spaced corn, but a gain of

9 bushels over ordinary-spaced kafir and 4.7 bushels over double-spaced kafir. More adequate comparisons of corn with other crops and preparations for winter wheat have been made elsewhere in this bulletin. The object of these rotations is to afford a comparison of corn with kafir and of ordinary spacing with double-spaced plantings of these crops.

TABLE 10.— *Yields of wheat on disked ground following corn or kafir with different spacings at the Fort Hays branch station for the 5-year period from 1916 to 1920, inclusive.*

Year.	Yields per acre (bushels).			
	After corn.		After kafir.	
	Rotation 149, ordinary spaced.	Rotation 150, double spaced.	Rotation 349, ordinary spaced.	Rotation 350, double spaced.
1916	34.1	39.1	15.1	31.1
1917	3.1	3.3	.0	.6
1918	13.3	10.1	1.0	3.8
1919	18.1	18.3	20.6	18.6
1920	25.1	28.6	19.2	23.5
Average	18.7	19.9	11.2	15.5

The ordinary-spaced corn averaged 2.1 bushels of grain and 2,531 pounds of stover. The double-spaced corn averaged 8.8 bushels of grain and 2,286 pounds of stover. The ordinary-spaced kafir averaged 10.7 bushels of grain and 4,748 pounds of stover. The double-spaced kafir averaged 15.1 bushels of grain and 3,627 pounds of stover.

WHEAT IN MISCELLANEOUS ROTATIONS.

In Table 8 were given the yields of wheat on two plats in rotation No. 401 and one plat in rotation No. 402. For comparison with these the yield of wheat on the N–O plats in the methods-of-fallow experiment for the same years is included in the table. Rotations Nos. 401 and 402 were started in the spring of 1913. Spring wheat was sown in them that year, so that results with winter wheat are available for only the 7-year period from 1914 to 1920, inclusive.

No. 401 is a 4-year rotation of kafir listed, fallow, winter wheat on fallow, and winter wheat on early-plowed wheat stubble. The wheat on fallow has averaged 20.7 bushels and on fall-plowed wheat stubble 21.4 bushels. These figures present the interesting evidence of wheat after wheat yielding more than after fallow. The yield of straw supports the evidence of the yield of grain. As these are in a rotation where one follows the other, there is no ground for an argument that one has any soil advantage over the other. The yield following fallow is a little low as compared with that on fallow after kafir in the near-by 3-year rotations Nos. 501 to 510, inclusive, con-

sidered in the following pages, and it is also low in comparison with wheat on alternate fallow in methods of fallow. These latter are in fairly good agreement. It has been shown that kafir has a very depressing effect upon the yield of wheat that follows it immediately, but the evidence as a whole indicates that this effect is eliminated by a fallow. No. 402 is an adjoining rotation of kafir listed, fallow, winter wheat on fallow, and kafir listed. The wheat on fallow in this rotation has averaged only 17.6 bushels. This seems to show that the growth of two crops of kafir in succession establishes a depressing effect that persists through a fallow. This possible conclusion is subject to a reasonable doubt by the yields in 1914, when the rotations had not run long enough to differentiate the wheat on fallow in rotations Nos. 401 and 402, but when the yield of wheat in No. 402 was low.

The kafir following wheat in rotation No. 410 has averaged 22.6 bushels per acre; following wheat in rotation No. 402 it has averaged 20.4 bushels, and following kafir in the same rotation it has averaged only 14.7 bushels. While a potential difference of soil and location might be established between rotations Nos. 401 and 402, the two plats of kafir in No. 402, like the two plats of wheat in No. 401, are grown on the same ground, one following the other from year to year over the four plats that constitute the rotation.

These 4-year rotations were started for comparisons with the 3-year rotations of kafir, fallow, and wheat that are considered in the following pages to determine the effect of lengthening them by introducing a second crop of wheat or a second crop of kafir. Their evidence is very positive. The second crop of wheat (wheat on early-plowed stubble of wheat raised on fallow) has an exceptionally favored position. The rotations should be lengthened by increasing the number of wheat crops. On the other hand, the second crop of kafir (kafir following kafir) is depressed to about two-thirds the yield of kafir following wheat. There is also indication, although the evidence is by no means conclusive, that this doubling of the kafir crop establishes a depressing effect that is not entirely eliminated by a year of fallow.

In 1916 two 4-year rotations were started. Rotation No. 403 is corn on spring plowing, barley on disked corn ground, winter wheat on fall-plowed barley stubble, and winter wheat on fall-plowed wheat stubble. Rotation No. 404 is the same in all respects except that kafir takes the place of corn.

The 4-year average yield of the wheat on fall-plowed barley stubble has been 17 bushels in each rotation. The wheat following wheat has averaged 17.2 bushels in rotation No. 403 and 16.1 bushels in No. 404.

The barley has averaged 23.8 bushels following corn and 22.5 bushels following kafir. These rotations show little or no depression

in the yield of spring-sown barley as a result of its following kafir, which is very contrary to the effect of kafir on fall-sown wheat, as shown in rotations Nos. 149, 150, 349. and 350, which have been considered.

WHEAT IN 3-YEAR ROTATIONS OF KAFIR, FALLOW, AND WHEAT.

In 1913 two series of ten 3-year rotations were started. These 20 rotations are all fallow, winter wheat, and kafir. The first series, numbered from 501 to 510, inclusive, was planned primarily to study methods of raising kafir on wheat stubble, but two of the rotations, Nos. 501 and 502, vary from the others in the method of fallow. The cultivation for fallow in rotation No. 501 is started in the fall by plowing to a depth of 12 to 14 inches with a deep-tillage machine. The plat to be fallowed in rotation No. 502 is dynamited before listing in the fall. A half stick of dynamite is shot at a depth of 3 feet in holes 16 feet apart. The first year 20 per cent dynamite was used, but since then 40 per cent has been used. This plat and the plats to be fallowed in rotations Nos. 503 to 510, inclusive, are listed in late fall. During the spring the lister ridges are leveled by such cultivation as may be necessary to prevent weed growth. About midsummer the plats are all plowed. Enough cultivation is given after plowing to prevent weed growth and to prepare a good seed bed for winter wheat. The fallows are seeded uniformly to wheat in the usual manner, with no special treatment.

These rotations are so arranged that the fallow, wheat, and kafir each occupy a solid block of 10 plats side by side, arranged from north to south in numerical order. The wheat stubble is prepared for kafir in the several rotations as follows:

Rotation 501: Fall list, cultivate ridges down in early spring, list at planting time (deep tilled for fallow).
Rotation 502: Same as No. 501 except dynamited for fallow instead of deep tilled.
Rotation 503: Double-disk in July or August, fall list, cultivate ridges down in early spring, list at planting time.
Rotation 504: Fall list, cultivate ridges down in early spring, list at planting time.
Rotation 505: Fall list, ridges untouched until planting time, then split ridges.
Rotation 506: Fall list, work with harrow in spring, list in same furrows at planting time.
Rotation 507: Fall list, work with harrow in spring, split ridges at planting time.
Rotation 508: Early spring list, ridges untouched until planting time, plant in same furrows.
Rotation 509: Double-disk in spring, list at planting time.
Rotation 510: Untouched until planting time, then list.

The yields of both wheat and kafir in these 10 rotations for the 7-year period from 1914 to 1920, inclusive, are given in Table 11.

Careful study of the data from these and the 10 companion rotations shows the plat variation or experimental error to be so high

in relation to the differences in yield exhibited from the different rotations that for the purposes of the present bulletin only limited consideration and conclusions are warranted.

TABLE 11.— *Yields of wheat and kafir in rotations Nos. 501 to 510, inclusive, at the Fort Hays branch station for the 7-year period from 1914 to 1920, inclusive.*

Year and crop.	Yields per acre for the 10 rotations (bushels).									
	No. 501.	No. 502.	No. 503.	No. 504.	No. 505.	No. 506.	No. 507.	No. 508.	No. 509.	No. 510.
Wheat:										
1914	24.8	24.3	25.5	26.8	26.8	26.7	26.0	24.3	23.9	23.5
1915	14.9	13.5	14.4	12.5	13.9	13.1	14.9	14.4	17.0	15.9
1916	38.8	32.9	35.5	37.8	39.7	40.3	40.5	38.7	37.7	33.2
1917	10.2	14.3	15.0	12.3	14.4	14.6	16.4	15.5	15.3	11.1
1918	6.9	10.8	10.1	11.2	12.8	12.4	12.3	12.9	12.3	12.0
1919	10.9	10.4	10.7	11.0	12.6	12.8	12.3	12.0	10.9	10.1
1920	37.5	39.0	39.3	35.8	37.9	31.2	37.2	37.7	37.5	33.3
Average	20.6	20.7	21.5	21.1	22.6	21.6	22.8	22.2	22.1	19.9
Kafir:										
1914	2.6	5.0	6.4	5.9	5.8	6.6	6.9	8.1	4.8	4.6
1915	47.8	43.3	43.7	48.8	46.9	50.2	35.0	39.8	29.9	30.3
1916	11.8	8.8	10.7	13.8	19.8	15.8	13.7	10.6	7.9	2.6
1917	8.9	2.9	3.4	3.1	1.7	1.8	1.3	.9	.6	.4
1918	14.1	6.8	5.3	4.5	3.3	3.9	4.8	2.5	3.7	2.7
1919	34.5	31.6	32.3	33.5	38.3	46.6	35.2	40.9	38.4	28.4
1920	78.2	62.1	68.5	68.1	68.0	68.0	67.3	63.1	47.6	38.3
Average	28.3	22.9	24.3	25.4	26.3	27.6	23.5	23.7	19.0	15.3

Comparing the yields in rotations Nos. 501 and 502 with those from the other rotations it is very evident that neither the deep plowing of No. 501 nor the dynamiting of No. 502 has been effective in increasing the yields of wheat on the fallow receiving such treatment. The preparation of the wheat stubble for kafir on these plats is the same as in rotation No. 504. Comparing the yields of kafir in Nos. 501 and 502 with that in No. 504 especially and with the other rotations in general, there appears good basis for the conclusion that the deep tillage of No. 501 has some years extended its effect to the kafir crop and increased its yield. Special attention is directed to the yields in 1917, 1918, and 1920, when this effect was shown. By the same comparisons the aftereffect of the dynamite has been to depress the yields of kafir the second year after its use. This may not be the correct interpretation, although the evidence to support it is nearly as strong as that indicating an increase from deep tillage. Passing over the other methods to the last two, it is evident from comparison of them with the others that the yield of kafir is increased by cultivation that prevents the growth of vegetation during the spring before planting. The double-disking in the spring which rotation No. 509 receives is not sufficient to do this, and a marked decrease from the others is noted in its yield. A still further decrease is noted in the yield in rotation No. 510, which receives no cultivation at all until it is planted with a lister. This method is sometimes

almost or quite impracticable on account of the growth of weeds and more especially the growth of volunteer wheat, which reaches nearly or quite the heading stage by the time kafir is planted. In the case of rotation No. 510 this seems not only to have reduced the crop of kafir about one-third, but to have continued through the fallow and some years reduced the yield of wheat grown on it.

The second series of 10 rotations, numbered from 551 to 560, inclusive, was planned to study the use of manure applied directly to the wheat at different rates, applied to kafir at different rates, and the effect of a light dressing of straw on winter wheat.

Except for the manure or straw that they receive, the treatment of all 10 rotations is uniform. The fallow and the wheat on fallow are the same as outlined for rotations Nos. 503 to 510, inclusive. After the wheat is harvested the ground is plowed in the fall, cultivated in the spring, and the kafir planted with shallow listing.

Rotations Nos. 551, 552, and 553 receive no manure and are duplicates run as checks on those receiving treatment.

The winter wheat in rotation No. 554 receives a top-dressing of straw late in the fall at the rate of 2 to 3 tons per acre. To hold it in place, the straw is cut into the ground with a packer.

Barnyard manure is applied as a top-dressing at the same time to the wheat in rotation No. 555 at the rate of 3 tons per acre, and to the wheat in rotation No. 556 at the rate of 6 tons per acre.

In rotations Nos. 557, 558, 559, and 560 barnyard manure is used preceding the kafir crop. It is spread on the plowed land in November or December at the same time the wheat is top-dressed. It is used at the rates of 3 tons per acre in rotation No. 557, 6 tons in No. 558, 9 tons in No. 559, and 12 tons in No. 560.

As with rotations Nos. 501 to 510, inclusive, these are arranged so that the fallow, wheat, and kafir each occupy each year a solid block of 10 plats with the rotations arranged from north to south in the order in which they appear in Table 12. This table gives the yields of wheat and kafir in these 10 rotations for the 7-year period from 1914 to 1920, inclusive.

If it were not for the three check rotations which appear at intervals among the manured ones, one might attempt to discuss the effects of manure applied at different rates and to different crops in the rotations. But with the data as they are, the only conclusion that can be arrived at from a study of the yields year by year and of the average from the entire series of years is the general one that both barnyard manure and straw have been ineffectual in increasing the yields of either wheat or kafir. To one familiar only with soils that respond to manure or on which it is a necessity to crop production, such a result may seem almost incredible, but it is a rather usual one on the Plains and the prairie soils of the dry-farming section. It is recog-

nized, of course, that the length of time these experiments have run is insignificant in comparison with the time these soils will be cropped. Regardless of the conclusions to which it may lead, this work is considered of the greatest importance and will be continued.

TABLE 12.— *Yields of wheat and kafir in rotations Nos. 551 to 560, inclusive, at the Fort Hays branch station for the 7-year period from 1914 to 1920, inclusive.*

Crop and year.	Yields per acre for the 10 rotations (bushels).									
	No. 554, straw on wheat, 3 tons.	No. 551, check, no manure.	No. 555, manure on wheat, 3 tons.	No. 556, manure on wheat, 6 tons.	No. 552, check, no manure.	No. 557, manure on kafir, 3 tons.	No. 558, manure on kafir, 6 tons.	No. 553, check, no manure.	No. 559, manure on kafir, 9 tons.	No. 560, manure on kafir, 12 tons.
Wheat:										
1914	20.2	22.9	26.0	27.0	24.2	25.0	26.2	26.5	27.4	30.3
1915	19.7	17.8	16.1	15.3	14.2	14.5	16.2	19.2	17.4	17.3
1916	32.6	29.4	27.3	33.9	37.0	38.6	38.8	40.8	37.4	35.3
1917	2.2	6.8	6.7	6.8	7.5	8.7	8.9	7.1	8.8	11.8
1918	10.8	11.5	11.2	10.5	10.8	10.4	8.8	11.3	9.5	10.2
1919	12.2	13.6	12.2	13.0	10.6	10.6	12.3	11.6	10.5	11.1
1920	27.3	30.3	29.6	36.0	37.8	38.3	32.9	37.1	33.3	32.7
Average	17.9	18.9	18.4	20.4	20.3	20.9	20.6	21.9	20.6	21.2
Kafir:										
1914	6.8	6.8	4.8	5.5	8.5	7.8	6.9	8.8	9.2	7.7
1915	58.2	55.5	52.8	55.3	54.3	53.4	51.9	50.4	52.3	47.9
1916	7.5	13.8	18.2	11.6	12.1	5.8	2.2	1.3	1.1	.6
1917	0	0	0	0	.1	.2	.1	.2	.2	.3
1918	.2	.4	.4	.4	.4	.5	.5	.5	.5	1.0
1919	28.3	36.3	35.8	37.2	39.7	32.0	27.7	29.6	23.3	22.2
1920	59.5	54.9	59.6	67.7	67.4	63.6	65.3	66.6	70.8	66.3
Average	22.9	24.0	24.5	25.4	26.1	23.3	22.1	22.5	22.5	20.9

In 1919 experiments were started to determine the effect of commercial fertilizers on wheat production. At the same time extensive work was started in further methods of seed-bed preparation for wheat following winter wheat, and a test of the disk and lister drills on the different seed beds. It is too early to draw any conclusions from these experiments.

SUMMARY.

The Fort Hays branch station is located in Ellis County, Kans. This county is in the western tier of the solid block of "million-bushel" wheat counties in that State. Statistics of the Kansas State Board of Agriculture [9] show that the agriculture of this section has been stabilized for 30 years by devoting nearly three-fourths of the cultivated acreage to winter wheat. The statistics also show that during this period there has been no change in yields. The average yield of Ellis County for the 30 years from 1891 to 1920, inclusive, is only 9.6 bushels per acre.

The statistics of crop acreage show that if every acre in other crops were seeded to wheat it would still be necessary to sow approximately two-thirds of the wheat following wheat. About one-half of the other

[9] Kansas. State Board of Agriculture. Biennial Report, v. [3–27], 1874–1919–20. Topeka, 1874–1921.

third, or one-sixth of the total wheat acreage, might be sown following corn, and the other sixth following miscellaneous crops, chiefly grain and forage sorghums. The greatest cultural problem in terms of acres involved, consequently, is how to prepare wheat stubble for wheat.

Results of experiments in methods of wheat production conducted cooperatively at the Fort Hays branch station are available for the 14-year period from 1907 to 1920, inclusive.

During this entire period wheat has been grown continuously after wheat by several methods of cultivation. There are 90 days between harvest and seeding. Late plowing, 73 days after harvest and 17 days before seeding, has averaged 10.5 bushels per acre. This is the lowest yielding method under trial, but is practically the same as the Ellis County average of 10.2 bushels for the same period. Early plowing, 32 days after harvest and 58 days before seeding, has averaged 14.6 bushels per care. Early plowing subsoiled has averaged 17 bushels, and land listed instead of early plowed has averaged 17.3 bushels. Land alternately fallowed and cropped to wheat has averaged 20.3 bushels.

During the 7-year period from 1914 to 1920, inclusive, surprising success has attended the growth of wheat sown in wheat stubble either disked or uncultivated. This method has averaged higher yields than late plowing and nearly as much as early plowing.

The results of the experiments show the possibility of increasing the county average. Land that can be early plowed or listed can not be fallowed profitably, although the yield per acre might be increased somewhat. Land that can not be prepared early could be fallowed more profitably than plowed late and seeded. If free from perennial weeds or grasses it could still more profitably be seeded in the stubble, with no preparation unless perhaps a double-disking.

Studies of the method of fallow and the length of the fallow season show that the effectiveness of fallow is not increased at this station by cultivation for a longer period than the growing season of the fallow year. The greater part of its benefits may be realized by cultivation in the period between harvest and seeding. The essential factor of the fallow is the maintenance of a bare surface, prevention of the growth of vegetation. The cultural methods by which this is accomplished are of minor importance from the standpoint of resultant yield. Their importance is in their relative cost and their effectiveness in preventing soil blowing.

Green manures, although more expensive, do not increase yields over bare fallow or even over early plowing of land from which a crop is harvested.

The results of experiments with sod crops in rotations show them to be relatively unsuccessful themselves. Alfalfa is more successful than brome-grass, but is very depressing in its effect upon following crops. Wheat after corn averages about the same as the better methods of wheat after wheat. Kafir produces heavier yields of both grain and forage than corn, but wheat can not be sown immediately after kafir without great reduction in yield. The depressing effect of kafir is, however, eliminated by a single year of fallow or cropping. Barley, which is spring sown, follows kafir as well as it does other crops and produces relatively good yields. Winter wheat follows barley as well as it does wheat or other crops. This establishes in the rotation a place for barley between kafir and winter wheat.

The use of barnyard manure at different rates and in different positions in 3-year rotations of kafir, fallow, and winter wheat for the 8-year period from 1913 to 1920, inclusive, has not had a measurable effect upon the yields of either wheat or kafir.

The experiments do not indicate that a reduction of the proportion of wheat to other crops would necessarily result in an increased average yield per acre of wheat. They do indicate, however, that the present average yield per acre is not as high as it should be. The most fertile field for the control of yields is the 90-day period between harvest and seeding. The more completely this is made a cultivation period the higher will yields rise above the minimum at which they now rest. An increase of 50 per cent is not impossible, and some part of it should be realized through greater timeliness and efficiency of operations.

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